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Effect of drought stress on qualitative characteristics of canola cultivars in winter cultivation

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A B S T R A C T

To determine the appropriate canola cultivars for winter cultivation under late-season drought stress conditions, a factorial split-plot test was conducted in a complete randomized blocks design with three replications for two cultivation years (2014–2016) in Karaj, Iran. In this work, cultivations at two levels included fall cultivation (Oct. 7) and winter cultivation (Feb. 4). The irrigation was conducted at three levels including routine irrigation (control), irrigation interruptions from flowering and pod formation stage in factorial status in main plots and five *Brassica napus* L. cultivars including Sarigol, Delgan, Jacomo, Jerumeh and Hyola 401 in subplots. The interaction effect of cultivation date × irrigation × cultivar on the features of palmitic acid, linolenic acid, linoleic acid, oleic acid, erucic acid, glucosinolate and oil yield was significant at the level of 1%. The results indicated that Delgan cultivar with the highest oil yield (1582 kg/ha) in the winter cultivation date and normal irrigation conditions as well as with standard levels of erucic acid and glucosinolate can be effective in canola cultivation in the new stage of winter cultivation. Moreover, in winter cultivation and in the late-season drought stress conditions, hybrids Hyola 401 with the highest seed yield, and standard oligosaccharide and glucosinolate can also be recommended in late-season drought stress conditions.

1. Introduction

One of the main strategies to provide some edible oil, press cake, as well as cereals, especially wheat and barley, in cold temperate regions, is to consider the development of canola cultivation. In this regard, it is necessary to determine the appropriate cultivars for winter cultivation and water deficit conditions. Hence, finding cultivars yielding acceptable economic performance and standard qualitative characteristics in the new cultivation status and late-season drought stress, it can attempt practically to develop canola cultivation in arid and semi-arid regions with moderate cold climate effectively. Different varieties of canola contain 37% to 47% seed oil (Kadivar et al., 2010), moreover, yield and seed oil percentage are important in the profitability of canola production (Robertson and Holland, 2004).

The amount of seed oil is affected by drought stress (Shahsavari and Dadrasnia, 2016; Tohidi-Moghaddam et al., 2011) and temperature (Aslam et al., 2009) during the seed filling period. The combination of canola fatty acids contains 7% saturated fatty acids, 66% mono-unsaturated fatty acids and 27% multi-unsaturated fatty acids, and canola varieties have a significant difference in terms of the composition of fatty acids of seed oil (Kadivar et al., 2010). The quality of canola oil is mainly determined by the amount of oleic, linoleic and erucic fatty acids and it is highly influenced by environmental conditions (Enjalbert et al., 2013), cultivar type (Nasr et al., 2006 and Javidfar et al., 2007), and the length of the phonological stages (Pritchard et al., 2000).

Drought is the most important limiting factor for plant growth and agricultural production around the world, especially in arid and semi-arid regions (Sun et al., 2013; Shahsavari et al., 2014). Under drought stress conditions, the amount of saturated fatty acids of the seed oil decreases, which is associated with a shorter growth period (Shekari et al., 2015). Since almost 90% of the regions of Iran is considered as arid and semi-arid (Bannayan et al., 2010), climate change is expected to have a profound impact on the sustainable production of crops in arid and semi-arid environments such as Iran (Akhzari and Pessarakli, 2015). Canola is an appropriate plant for cultivation in arid areas as a result of high water consumption efficiency, relative tolerance to drought stress (Albarrak, 2006), and relative tolerance to soil salinity (Nielsen, 1997). Most arid and semi-arid regions with the moderate cold climate in the country have relatively proper rainfall in March and April, which meets some degree of water requirement of canola at the stem elongation stage. Therefore, saving water especially in the late-season irrigation (flowering, pod formation and seed filling stage),

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which coincides with the early irrigation of spring cultivations is significantly important, where farmers mostly do not have enough water to devote to both cultivations. Moreover, irrigation interruption in these stages causes 2–3 times less irrigation (saving between 1280–1920 m^3/ha) than the normal irrigation conditions (control). Furthermore, for sustainable development of cultivating this product, along with increased production per surface area, it was necessary to consider the critical factor of cultivation time limitation. Providing appropriate strategies such as selection of genotypes with a favorable reaction in the new winter cultivation, the time restriction of a 15–20 days fall cultivation will be removed in cold temperate regions for canola cultivation. The present study aimed to determine the suitable varieties of canola for winter cultivation under late-season drought stress conditions.

2. Materials and methods

To investigate the effect of drought stress on qualitative traits of canola cultivars in winter cultivation, a factorial split-plot test was conducted in a complete randomized blocks design with three replications in the cultivation years of 2014–2015 and 2015–2016 in Karaj (Iran) with the geographical coordinates of 6′ and 51°E and of 49′ and 35°N, respectively, and the height of 1313 m above sea level. Based on the average 30-year meteorological data of Karaj, the average annual rainfall in the region is 243 mm and the rainfalls are mainly in late fall and early spring. The meteorological statistics of the test site during the two cultivation years are presented in Fig. 1. The texture of the site soil was clay loam. The specifications are presented in Table 1.

In this study, cultivation date was determined on two levels including fall cultivation (Oct. 7) and winter cultivation (Feb. 4). Irrigation in three levels including normal irrigation (control) and irrigation interruption after flowering and pod formation stage was considered as the main factor. Moreover, *Brassica napus* L. cultivars, Sarigol (mid season), Delgan (early season), Jacomo (late season), Jeromeh (late season) and Hyola 401 (early season) were as the subfactor.

Each experimental plot included six 6-m lines with 30 cm space between the lines. The space between the plants along the line was 5 cm and 2 lateral lines were considered as margins. Consumed fertilizers based on soil test were: 1) 150 kg/ha of ammonium phosphate and 150 kg/ha of potassium sulfate as a basis for preparing seedbed, 2) Urea was applied thrice at 350 kg/ha (100 kg in the three-leaf stage, 150 kg in the stem elongation stage and 100 kg in the budding stage). All operations related to the harvesting except irrigation were carried out uniformly and according to the traditions of the area. Irrigation intervals were considered based on 80 mm evaporation from class A evaporation pan and 80% of consumed water at each irrigation was

Table 1
Physicochemical properties of soil collected from site study.

Depth (cm)	EC (ds/m)	pH	Organic Carbon (%)	N (%)	P (ppm)	K (ppm)	Texture
0–30	1.45	7.9	0.91	0.09	14.7	197	Clay loam
30–60	1.24	7.2	0.99	0.07	15.8	155	Clay loam

evaporated. The amount of water entering the farm was measured by the water meter. The number of irrigation frequencies in fall cultivation in control treatments, restricted irrigation from pod formation stage and flowering stage was 8, 6 and 5 times, respectively, and in winter cultivation it was 6, 4 and 3 times, respectively. Moreover, the amount of water consumed in these treatments in fall cultivation was 5120, 3840 and 3200 m^3/ha, respectively, and in winter cultivation were 3840, 2560 and 1920 m^3/ha, respectively.

To determine the percentage of seed oil, 5 g seed were selected from each plot and its percentage was determined by NMR (Nuclear Magnetic Resonance) German Broker Brand minispec mq20 Model based on the International Standard ISO 5511 (1992). For this purpose, after daily calibration of the device with a reference sample and calibration of the product with pre-prepared standard samples, at least 3 g of rapeseed was weighed and transferred to the special cell of the device. The cell containing the specimen was located in a special place and the amount of oil was recorded in the monitor for less than 1 min. (The amount of canola defined for the device marker is at least 3 g of canola, which in this experiment it was selected as 5 g). After determining the seed oil percentage, multiplying it in seed yield, the seed oil yield was calculated in kg/ha.

Gas chromatography (GC) was used to measure and to determine the fatty acids in the seed oil. Oil samples were extracted in triplicate from canola seed (100 g) according to the method described by Azadmard-Damirchi et al. (2005).

Fatty acid methyl esters (FAMEs) were prepared from the oil samples according to the method reported by Savage et al. (1997). Briefly, 2 ml of 0.01 M NaOH in methanol was added to a tube containing the oil sample (ca. 10 mg) dissolved in 0.5 ml hexane and then held in a water bath at 60 °C for 10 min. There after, boron trifluoride in methanol (20% of BF3 in methanol) was added and the samples held an additional 10 min in a water bath at 60 °C. The sample was cooled under running water and 2 ml of 20% (w/v) of sodium chloride and 1 ml hexane was added. After mixing completely, the hexane layer that contained the FAMEs was separated by centrifugation.

The FAMEs were analyzed by GC according to the method described by Azadmard-Damirchi and Dutta. (2006). The GC instrument was equipped with a flame ionization detector and a split/splitless injector.

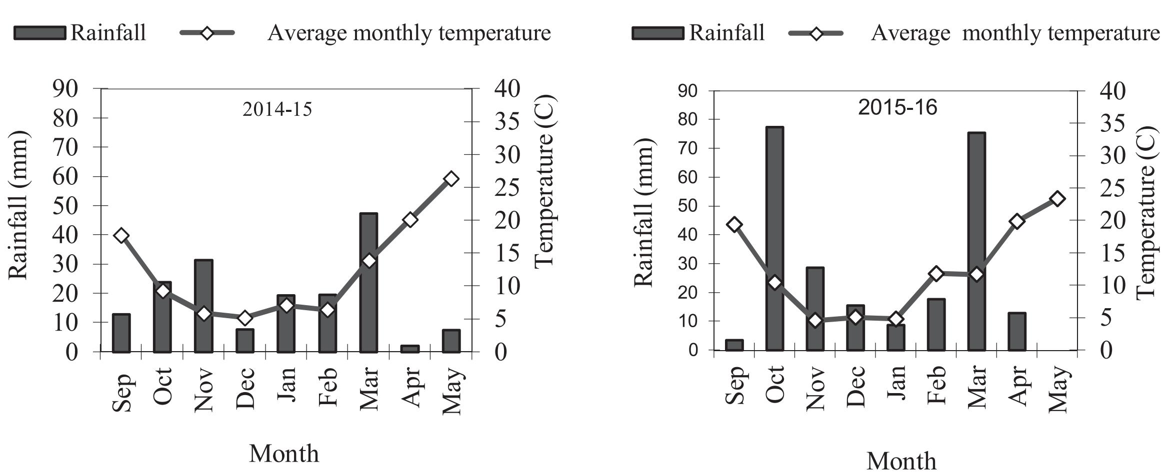

Fig. 1. Variation of temperature and rainfall in Karaj meteorology station during 2014–2016 growing seasons.